Learning Segment 2.0
Sandwich-Cookie Challenge

Learning-Segment Overview

Students will read through the challenge and briefly discuss the issue at hand, uncovering the apparent criteria and constraints of the challenge. They will then have 10-15 min to investigate the issue. Following this, the class will analyze the data the students collected to determine the quality and effectiveness of their work.

Learning Objectives

Students will:

- Develop a consistent procedure and carry it out consistently across trials.
- Discover the difficulty in replicating results within a procedure.
- Understand the need for consistency in tools and materials used across trials.
- Appreciate the need to run many trials to get representative data.
- Use histograms to determine if data is reliable.
- Learn about the role of human error in coming up with inconsistent results.
- Learn about the role of tool limitations in coming up with consistent results.
- Understand that the environment affects the consistency of results and is difficult to completely control.

Expected Duration: 1 instructional period

Materials

For each student group

- 1 large or small pipette
- 1 small plastic or paper cup
- 1 penny
- 1 sheet pre-labeled graph paper

Activity Set-Up and Preparation

Have supplies separated into piles and ready to hand out as soon as students read through the text introducing the challenge. Additionally, read through the student text completely so you are familiar with the text and what it discusses and tells students they will be doing. You might want to perform the test yourself to better understand how the tests work.

Enacting the Learning Segment

Engaging the Students

How Do You Know Your Answer Is Right If You Don't Know The Right Answer?

Begin this learning segment simply by reading aloud, as a class, through this section of the text. Go over the challenge, asking students to restate the challenge. Then, read through the Procedure section. Students are asked to come up with criteria and constraints for the challenge, and record them on a poster. As they progress through the activity, the students will come to an understanding that the criteria and constraint lists are longer that they had first conceived. Thus, their initial lists will probably be short.

They will most likely generate:
Criterion – Must drop water on the penny, determining the number of drops that fit on the surface.
Constraints – Must use pennies, water, and pipette.

Guiding Student Activity

First Attempt

Students make their first pass at dropping water onto the penny surfaces. They have 10-15 min to complete ten trials. Circulate around the room to get an idea of the procedure each group is designing and struggling with during the initial test. Remember, you should not expect perfection. In fact, some groups will fail at this task miserably. This is acceptable because it will allow you to discuss the importance of learning from the mistakes and failures of people. This way, the successful *and unsuccessful* groups will each have something to share and teach others.

Students will make several errors in testing consistently. Additionally, they will be inconsistent across groups. These teacher materials detail and discuss those differences later, but make notice of what you see as they test.

Stop for: Communicating Results, Share and Analyze the Sandwich-Cookie Data

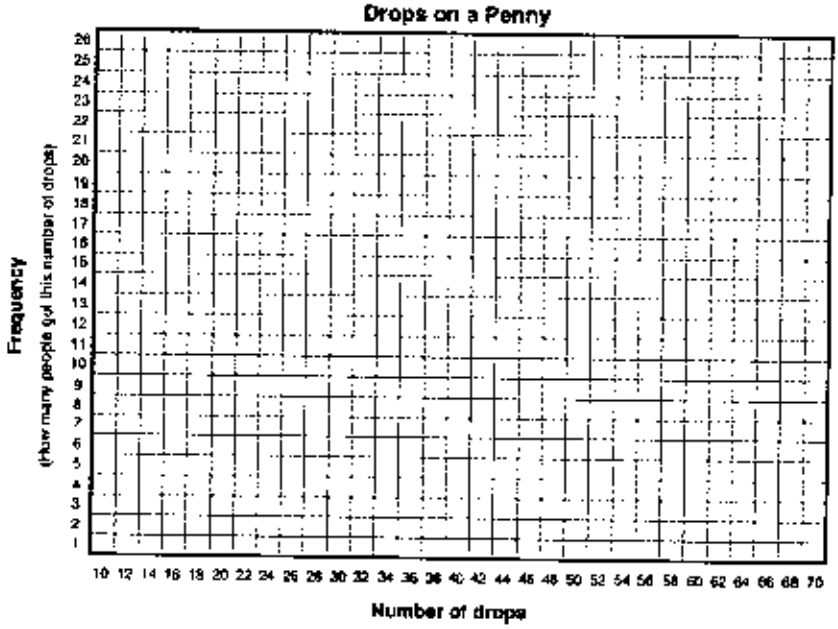
Once students have finished their tests, every group reports their data. Have the students read this section of their student text. You will need to have two things:
- photocopies of the graph paper, and
- an overhead copy of the same graph paper.

It would be to your advantage to have the axes already drawn and labeled on the graph paper.

You will be constructing a histogram, a special type of bar graph. It is a graphic representation of a frequency function. A histogram displays the number of times an item or an event in a given category occurs.

Students read out their individual trials, and you place an "X" on the graph for every data point. For example, if a students calls out, "20" you would place an "X" above the number 20 on the *x*-axis. If another "20" is called, place that X directly above the previous X. As the number 20 is

called out, the stack of Xs grows. The height of the column of Xs, at any one number along the *x*-axis, displays the number of times the number "20" was obtained during testing by the class.



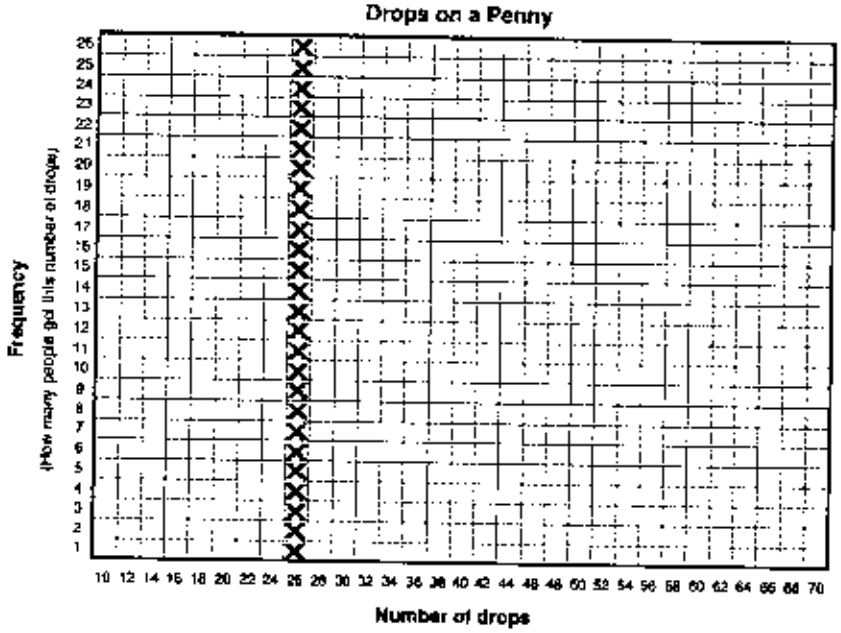
You should anticipate that students would have data between 10 and 70 drops, although some more extreme numbers have been reported. You might want to find out the high and low values from the class before begin your recording so that you will know how to label the columns in your histogram. Every group's data is recorded on this same histogram.

Once all data has been reported and recorded, ask your students a very simple question, "How many drops fit on the penny?" Students will probably do one of two things:

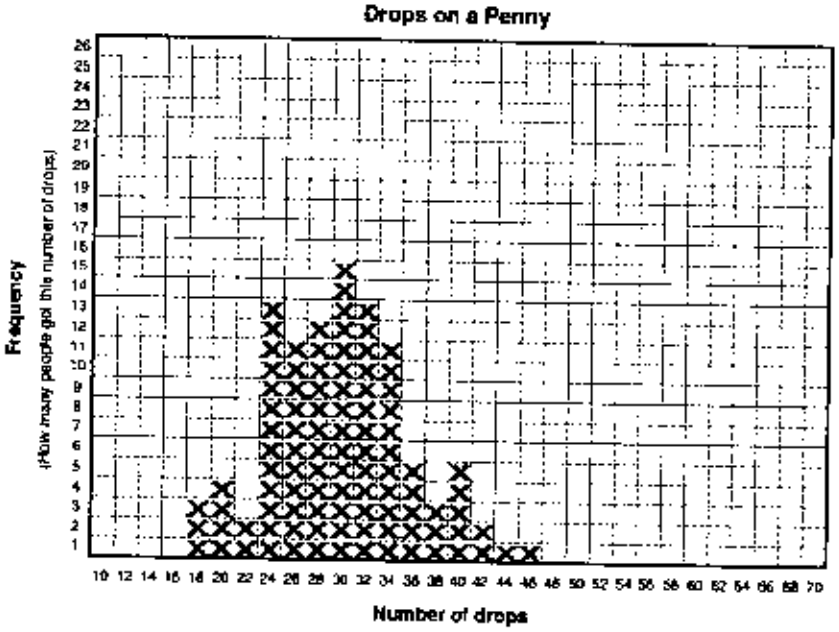
1. They will declare the number is the one with the greatest frequency. Thus, if the 24 column has the most number of Xs, then it must be the answer. Usually, this greatest frequency column might have four to eight Xs, but if you have one-hundred data points, that means only 4-8% of the trials came in at *24 drops*. This hardly justifies *24* as the answer to the question.

2. Students will look at the range of the data set and pick the average of the two points. So, if the first X appears at 15 drops and the last X appears at 75 drops, the average of those two numbers is 45. The interesting thing is, there might not actually be a data point at this number, or only 1-3 Xs. Once again, hardly seems fair to say the *45 drops* is the answer.

Histograms help you understand how well students are controlling their procedure and repeatedly measuring the same event. Theoretically, if the students completely control their investigation and accurately repeat their procedure, they should obtain the same number every time. This would produce a histogram with all of the data points in one column.



More than likely, at this point, the histogram will have a large range of numbers (with students reporting trials of anywhere from 10 drops to 100 drops), with very few repeating data points (multiple Xs in a column). Eventually, after students tighten-up their procedure, you are looking to see the columns of Xs bunching together over a very small range of numbers, say between 24-34. This bunching of data would indicate that students have standardized and repeated their procedure within a group *and* across groups. Do not reveal this fact to them just yet, however. Students will complete some Reflection Questions and the class will discuss how they might improve their procedure and data set.



Making Sense of the Activity

What Did Your Students Learn during This Segment or Lesson?

After completing the histogram, guide students to the Reflection Questions. These questions will help students review their procedure and data. If time permits, students can answer these questions during the remaining class period, or they can be completed for homework. You should review their responses at the beginning of the next class period.

Reflection Questions

Possible student responses to the Reflection Questions:

1. Did your group have any problems (mistakes, spills, etc.) during the tests? Describe each one.
   Answers will vary, but might include: we touched the water with the pipette, we held the pipette too high, we did not dry the test surface each time, sometimes we counted the drop that failed and sometimes we counted the one before it, we used different sides of the penny.

2. Did all groups get results similar to yours?
   Answers will vary, but realize, the data will probably be varied but certainly there will be overlap in the data points obtained.

3. What did the distribution, or spread, of data points on the histogram look like? What do you think this says about how reliable your lab is to determine the answer to the cookie company's question?
   Answers will vary. Students may answer, "There is a wide variety of answers to how many drops fit on a penny. At this point, the cookie company should not trust us! Our data is not consistent."

4. Why do you think there are differences between the data from various groups?
   Answers will vary, but students should notice that they all tested differently, and this could lead to problems in having consistent results.

5. How might your procedure and problems you had relate to the differences?
   Answers will vary, but students might suggest standardizing the procedure better.

6. What could the class do to get more consistent results in this challenge?
   Answers will vary. Students will begin suggesting ways to control how the test is completed.

If students completed the Reflection Questions for homework, take time during the next class period to review their responses. These questions will point your students in the direction of evaluating their test procedure. In general, first time through, the results are all over the board.

Help students see the trends or lack of trends in the data and that the class data is all over the place. Try to elicit explanations for the huge variations in the data. Why weren't results more consistent across groups? Expect to hear some of the following explanations, and help students arrive at some of these if they don't have ideas of their own:

1. Teams held droppers at different heights so sometimes drops bounced or rolled off and other times they fell hard enough to get through the surface resistance of the water and make the penny overflow early.
2. Teams used different droppers. (They will discover this if they watch each other carry out the procedure. Someone will notice that the dropper being used is different than the one they used.)
3. Some teams dropped drops faster or slower than others, so maybe more or less water came out of the dropper per drop.
4. Some teams dropped water until the penny overflowed and then subtracted one (this is called *running the procedure to failure*); some estimated that they had enough water on the penny and stopped.
5. Some teams have more worn pennies than others. Some have a better edge for holding the water on the surface.

A good way to elicit explanations is to have students whose data fell at different areas of the histogram to show the rest of the class how they carried out the procedure. Gear the conversation to focus on how differences in procedure can actually lead to differences in results. Students do not often see the effects that minor variations can have in an event. Here, the students begin to see this issue clearly.

Once enough possible explanations are out on the table, have the students generate a list of things that were done differently across groups – type of dropper, height of dropper, dropping water until failure, etc.

Possible Assessment

- Reflection Questions
- Histograms

Learning-Segment Sequence Review

1. Read and review the challenge.
2. Discuss and create initial criteria and constraints lists.
3. Students attempt initial Sandwich-Cookie drop and then report results.
4. Prepare histogram and discuss the large variation in the graph.
5. Complete and discuss Reflection Questions.

Teacher Reflection

- Were you able to let students make mistakes without correcting them?
- What were the common errors students made in running the procedure and measuring? How will you use those groups' mistakes to benefit the entire class?
- What aspects of the histogram were tricky, and how will you deal with those problems during the next set of tests?

Learning Segment 2.1
Rethinking Your Tests

Learning-Segment Overview

Students discover flaws in their testing procedure and then work together to create a new test procedure.

Learning Objectives

Students will:

- Develop a consistent procedure and carrying it out consistently across trials.
- Discover the difficulty in replicating results within a procedure.
- Understand the need for consistency in tools and materials used across trials.
- Appreciate the need to run many trials to get representative data.
- Use histograms to determine if your data is reliable.
- Learn about the role of human error in coming up with inconsistent results.
- Learn about the role of tool limitations in coming up with consistent results.
- Understand that the environment affects the consistency of results and is difficult to completely control.

Expected Duration: 1 instructional period

Activity Set-Up and Preparation

Students read through the text that reviews the importance of controlling procedures and measurement. Read through the student text completely so you are familiar with the text and what it discusses and tells students they will be doing. You might want to perform the test yourself to better understand how the test works.

Enacting the Learning Segment

Engaging the Students

Display the previously constructed histogram, reminding students of the huge variation they have in their data set. They are probably aware of their lack of testing consistency from the Reflection Questions in Learning Segment 2.0. Inform students that, today, they will find a way to create a better, more reliable data set.

Guiding Student Activity

What Went Wrong?

Students read about the need to control their testing procedures and develop consistent measures to obtain useful data. Read this section aloud as a class, relating their errors to those alluded to in the text.

Stop for: Creating a Class Procedure

Lead students through a discussion to create a new test procedure. Record the steps on a poster or overhead. Each student should record the new procedure on a sheet of paper that they will reference later. Try to let the students discuss and determine the procedure. If students start to make an error, or they do not engage in a good practice, let them go. These errors will lead to variation in the data. This will be something that either they will discover during the second round of tests or you can discuss during the histogram drawing.

Your job is to facilitate the discussion and creation of their new procedure. This will build the collaborative culture in the classroom. Additionally, it will serve to build you as the *facilitator*, rather than the expert-know-it-all in the classroom. We want students to begin to see themselves and their classmates as a group of problem solvers that can work together to create solutions and ideas to solve the challenge.

Making Sense of the Activity

What Did Your Students Learn during This Segment or Lesson?

After completing the histogram, guide students to the Reflection Questions. These questions will help students review their procedure and data. If time permits, students can answer these questions during the remaining class period, or they can be completed for homework. You should review their responses at the beginning of the next class period. ~~If time permits, students can answer these questions during the remaining class period, or they can be completed for homework.~~ If it is homework, you should review their responses at the beginning of the next class period. These are some suggestions for answers to the reflection questions:

Reflection Questions

Possible student responses to the Reflection Questions:

1. What are three or four key differences between your previous procedure and the new class procedure?

   Answers will vary. give examples...

2. What variables are you now better controlling in the new procedure?

   Answers will vary. give examples...

3. In your opinion, what effect will this new procedure have in the variation of the data on the histogram?

   The data points should move closer to one another and begin to group around a certain number.

Possible Assessment

- Reflection Questions

Learning-Segment Sequence Review

1. Read and review text about creating consistent procedures and using consistent measures.
2. Discuss and create a class test procedure.
3. Students record the procedure.
4. Complete and discuss Reflection Questions.

Teacher Reflection

- What aspects of the procedure are still flawed? How will you help students focus on those aspects after the next round of testing?
- How did you facilitate the creation of the new test procedure so that it was student-centered?

Learning Segment 2.2
Re-Testing Your "Cookies"

Learning-Segment Overview

Students attempt their new testing procedure. The class creates and reviews a histogram of their new data.

Learning Objectives

Students will:

- Carry out the new procedure they developed consistently across trials.
- Discover the difficulty in replicating results within a procedure.
- Understand the need for consistency in tools and materials used across trials.
- Appreciate the need to run many trials to get representative data.
- Use histograms to determine if your data is reliable.
- Learn about the role of human error in coming up with inconsistent results.
- Learn about the role of tool limitations in coming up with consistent results.
- Understand that the environment affects the consistency of results and is difficult to completely control.

Expected Duration: 1 instructional period

Materials

For each student group

- 1 large or small pipette
- 1 small plastic or paper cup
- 1 penny
- 1 sheet pre-labeled graph paper

Activity Set-Up and Preparation

Try out the new procedure to see if you can spot the flaws and see what range of data it is likely to produce.

Enacting the Learning Segment

Engaging the Students

Display the new procedure and remind students of what ~~you~~ they completed in the previous Learning Segment. Students now have a new procedure that was designed to better control variables and measurement. Remind students they will need to record 10 *clean* trials.

Guiding Student Activity

Run Your New Sandwich-Cookie Test

Students read about running their new test, which reminds them that they will need to collect 10 trials. They once again have 10-15 min to collect their data.

Afterward, each student group reports their results and a histogram is created. Discuss with the students the variation they see.

Making Sense of the Activity

Room for Improvement?

The histogram data points should be closer, more clustered together if the students were actually able to run a better, more consistent test. If the data points are not more clustered, ask students if they realized any problems with their procedure during the tests. Do they see any areas where they could improve their procedure?

If so, revise the procedure. Students should record this new procedure for another round of testing. This time, each student will take home a set of the materials for a third round of tests as homework. (You may feel it best to do the third test in the classroom.) Remind students that they will need to complete the test in a setting where they can complete the procedure accurately if they are doing it at home. This would require a stable, flat surface, and no distractions from siblings or pets.

Students also need to complete the Reflection Questions. They return to class with their results and their answers. Take time to review the new data and subsequent histogram to see if they made further progress.

Reflection Questions

Possible student responses to the Reflection Questions:

1. How do the results from the last test compare to the ones from your first set of trials?
   The data is much more clustered around a smaller range of numbers.

2. Did you have any problems (mistakes, spills, etc.) during the tests? List them.
   Answers will vary, but hopefully there was little or none.

3. Did all groups get results similar to yours?
   The data points should all be close to one another.

4. What did the distribution, or spread, of data points on the histogram look like? What do you think this says about how reliable your lab is to determine the answer to the cookie company's question?

Most of the data points were stacked on top of each other across about five to seven columns.
We are able to produce more repeatable results with consistent trials,

5. Do you think it would ever be possible, given the materials and conditions you have in the classroom, to find the "right" answer? Why or why not?

There is probably too much human error involved in determining how many drops can fit on the penny using this equipment. In fact, our facility, the classroom, probably is not the best place to figure this out.

6. What do you think it would take to find the "right" answer?

It is possible that the "right" answer cannot be found, but maybe that's as good as we can do in science... getting close to understanding the right answer.

Possible Assessment

- Reflection Questions

Learning-Segment Sequence Review

1. Attempt new class procedure.
2. Build and analyze new histogram.
3. Students review and revise procedure if needed.
4. Students complete third round of tests with a revised procedure, and they complete the Reflection Questions.
5. Build and analyze new histogram and discuss their Reflection Question responses.

Teacher Reflection

- How did you facilitate the creation of the new test procedure so that it was student-centered?
- How were you able to focus attention on using data to evaluate the quality of testing procedures throughout the activity? What will you need to do to continue working this concept with your students?